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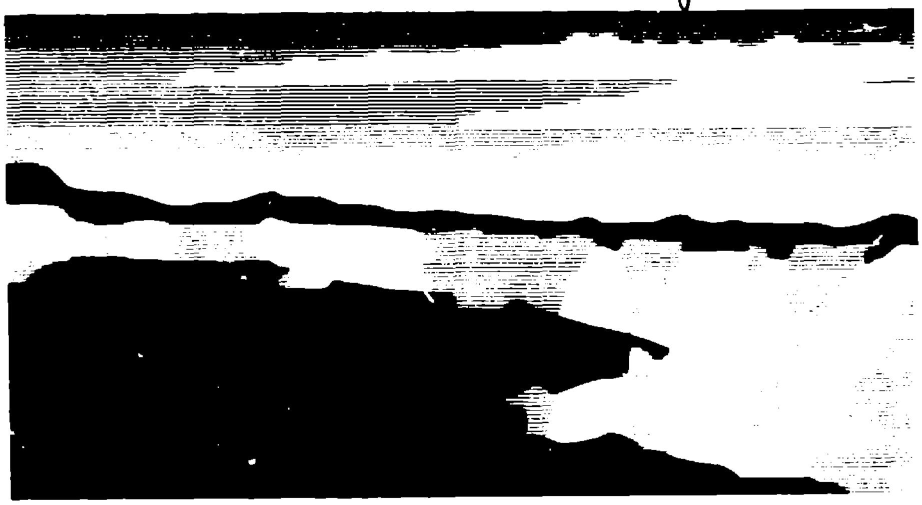

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A DEADTIME REDUCTION CIRCUIT FOR THERMAL NEUTRON COINCIDENCE COUNTERS WITH AMPTEK PREAMPLIFIERS*

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ABSTRACT

We have developed a deadtime reduction circuit for thermal neutron coincidence counters using Amptek preamplifier/amplifier/discriminator circuits. The principle is to remove the overlap between the output pulses from the Amptek circuits by adding a derandomizer between the Amptek circuits and the shift-register coincidence electronics. We implemented the derandomizer as an Actel programmable logic array; the derandomizer board is small and can be mounted in the high-voltage junction box with the Amptek circuits, if desired. Up to 32 Amptek circuits can be used with one derandomizer. The derandomizer has seven outputs: four groups of eight inputs, two groups of 16 inputs, and one group of 32 inputs. We selected these groupings to facilitate detector ring-ratio measurements. The circuit was tested with the five-ring research multiplicity counter, which has five output signals—one for each ring. The counter's deadtime was reduced from 70 to 30 ns.

INTRODUCTION

To decrease the problem of deadtime in multiplicity neutron counting, we implemented a 32-channel derandomizer to go in front of the coincidence counter electronics. Previously, the signals from each Amptek[1] preamp were ORed together to make one signal. This increased deadtime because data were lost due to simultaneous events being recording as one event. This arrangement is convenient but introduces an unnecessary deadtime. Because the triples count rates from neutron multiplicity counters are very sensitive to deadtime, the new circuit was designed to remove this source of deadtime.

The new design required 32 channels of input with each channel having a derandomizer that could record up to three separate events.

There are seven outputs. The 32 channels are first divided into 4 groups of 8 channels each and derandomized into 4 outputs. The 4 outputs are combined and again derandomized into 2 groups of 16 as 2 outputs and then into 1 output of 32 channels. These groupings were made to facilitate ring-ratio measurements.[2]

The 32 input signals are recorded asynchronously and derandomized at 10 MHz for each channel. The four groups of eight derandomizers are read out on a descending-order priority scheme one channel at a time. Only those channels in which events are recorded are interrogated. The outputs of the derandomizers are clocked at a 10-MHz synchronous rate and produce a 50-ns pulse for each event. A block diagram of the derandomizing circuitry is shown in Fig. 1.

The circuit was implemented in one Actel** field programmable gate array. The circuit can be divided into the four 8-input derandomizers with their priority circuits and the last stage derandomizers with their priority circuit.

The derandomizer on each input is made up of five Actel flip-flops and two exclusive OR gates. See Fig. 2. Two flip-flops are arranged into a 2-bit asynchronous ripple counter and two flip-flops are arranged as a 2-bit synchronous nonripple counter. Both counters count down, wrap around, and the counts of each counter are continually compared against each other. At equilibrium both counters have the same count. When an event comes in, the asynchronous counter counts down and registers a mismatch between the counters in the fifth flop-flop at the synchronous 10-MHz falling clock edge. The rising edge of the 10-MHz clock causes the synchronous counter to count down if the priority circuit selects this derandomizer with a low true on the ENA enable counting signal.

The first priority circuit is arranged so that channel 0 has the highest priority to be emptied.

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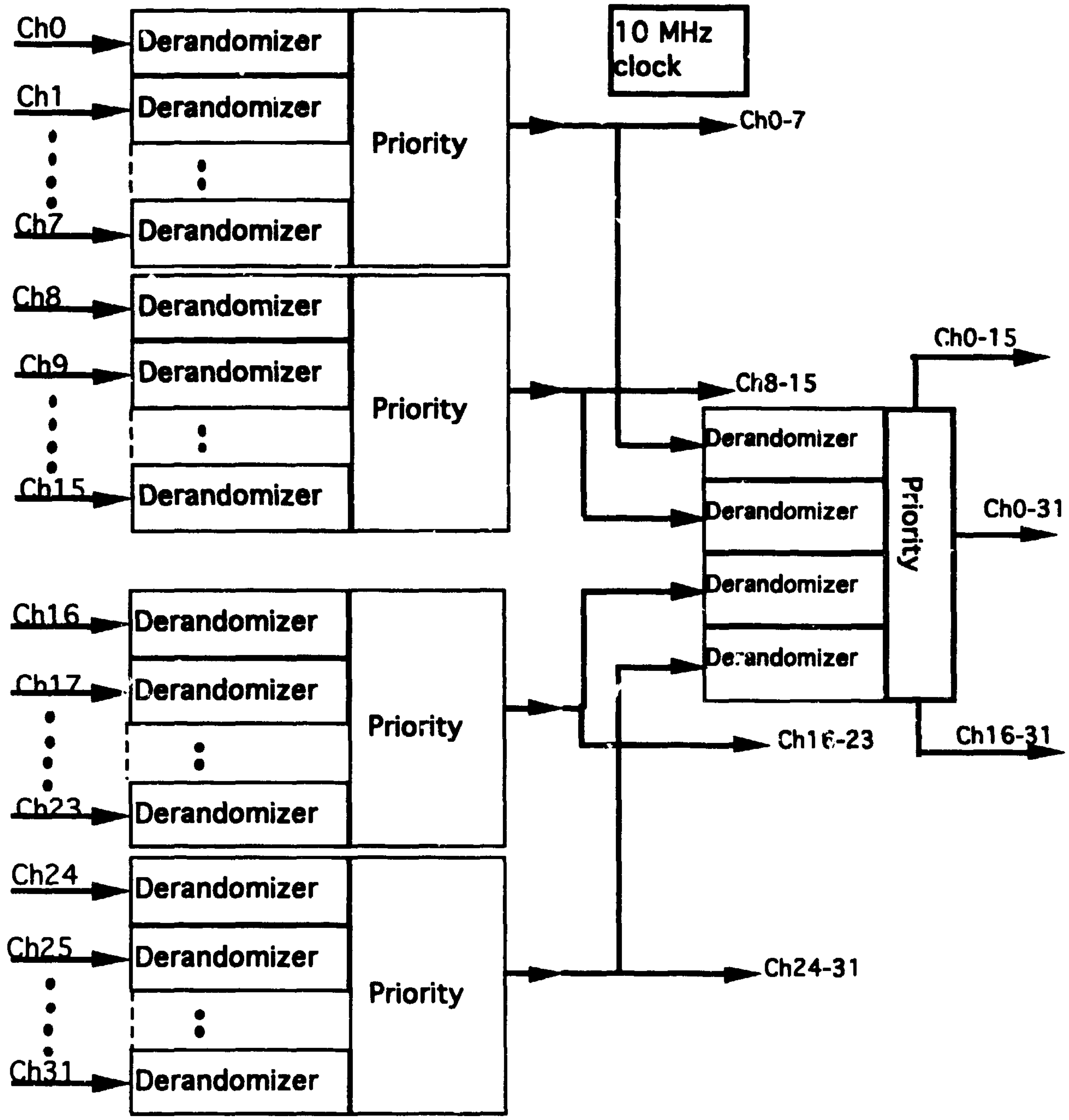

Fig. 1. B ock diagram of 32-input derandomizer.

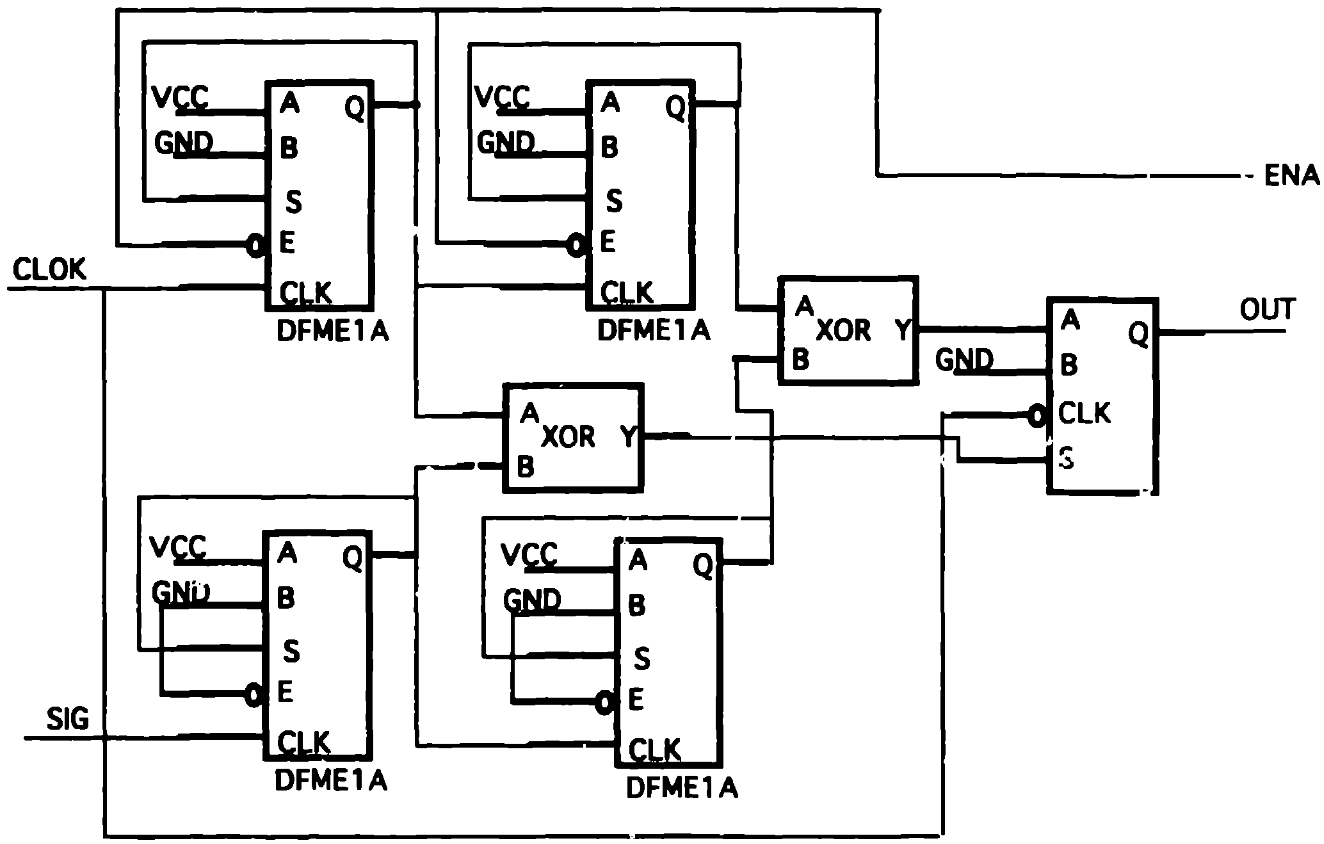

Fig. 2. The basic derandomizer.

Because it has the highest priority, it could be a one-deep derandomizer but for simplicity it was made the same as the other seven in the group. The second derandomizer will be emptied on the next clock cycle if the derandomizer ahead of it is already empty and so on. The seventh derandomizer will be emptied if all six derandomizers ahead of it are already emptied. A three-gate delay between channel 0 and channel 7 in the priority circuit, about a 27-ns delay, is the longest possible delay. The clock period is 100 ns with a 50-ns pulse; this is short enough to be well within the design limits.

The last stage of derandomizing is made up of four derandomizers. The highest priority derandomizer is a three flop-flop, one-deep derandomizer and is different from the other three. The succeeding derandomizers are seven deep. There are eight states in the derandomizers but one state is the no-events-recorded state. An external output is available from each of these derandomizers. The outputs from these last 4 derandomizers are serviced with a priority circuit resulting in the output of the total 32 channels.

MEASUREMENTS

The circuit was tested with the five ring research multiplicity counter[3] and ^{252}Cf neutron sources. The five ring counter has a separate output for each of the five rings, so the tests were done with five inputs to the derandomizer. Measurements were made with six ^{252}Cf sources (CR5, CR7, CR8, CR9, CR10, and CR11) separately centered in the detector. The total count rate varied from about 3000 counts/s for CR5 to about 750 000 counts/s for CR11. Long measurements were made (typically 12 hours each) so that the standard deviation of the counting statistics for the triples count rate was never worse than 0.5%. The measurements were made with the conventional Amptek configuration and with the new derandomizing circuit. The results are shown in Fig. 3, where the relative triples counts per fission are plotted vs the true singles rate for the six ^{252}Cf sources. For example, at 750 000 counts/s the triples counts per fission for the derandomizing circuit are down to 52% of the value at low count rates, whereas the triples counts per fission for the standard OR circuit are down to 8% of the value at low count rates.

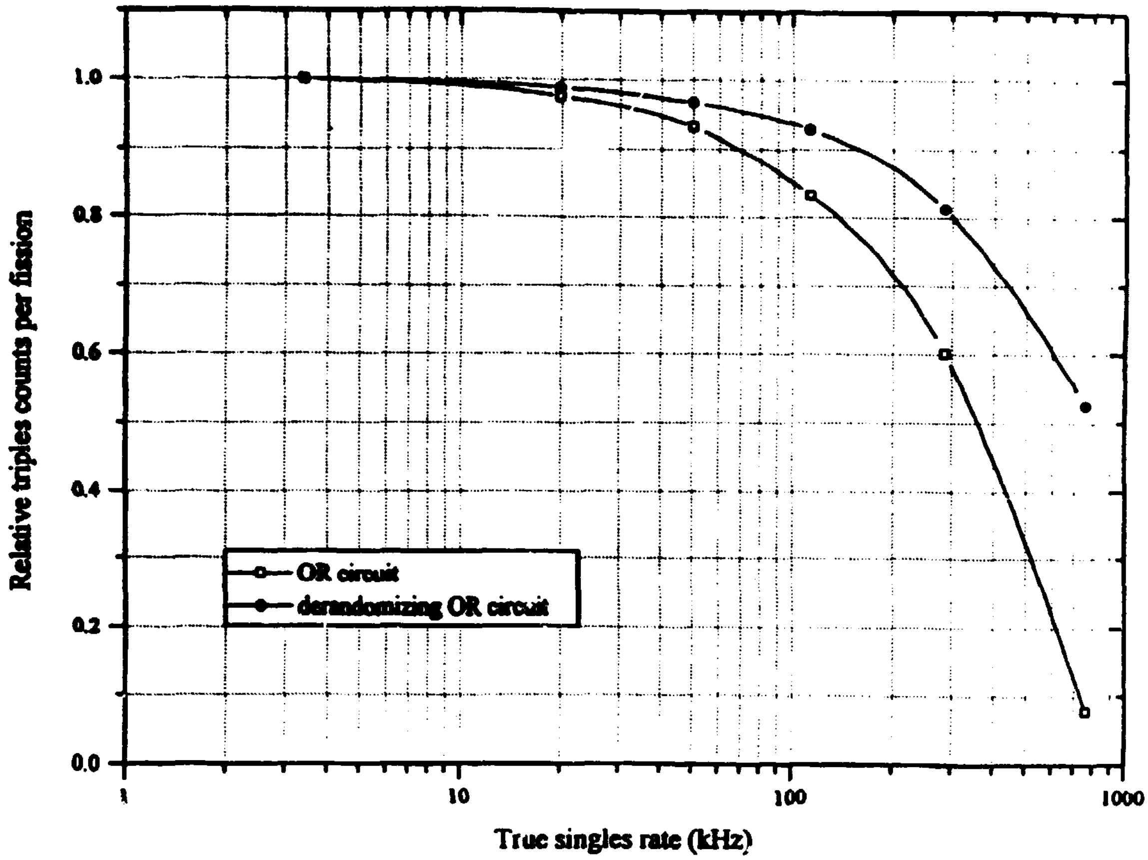

Fig. 3. Relative measured triples counts per fission vs true singles rate for the two OR circuits.

DATA ANALYSIS

The deadtime for each circuit was determined by fitting the ^{252}Cf data with the function

$$\left(\frac{D_m}{S}\right) = k \bullet \exp(-4\delta S) \ ,$$

where

δ = deadtime
S = true singles rate
D_m = measured doubles rate, and
k = a constant.

The deadtime for the standard OR circuit was found to be 70.2 ns and the derandomized OR circuit was found to be 30.4 ns. These values are close to the true deadtimes of the systems.

The triples rates measured with the derandomizing OR circuit were corrected for deadtime using the equations of Dytlewski.[4] If the true deadtime is used in Dytlewski's equations, the rates are undercorrected. For example, a deadtime of 30.4 ns gives a triples rate that is 8.3% low for the largest ^{252}Cf source because the equations are based on the assumption that the neutrons are randomly distributed and sampled. The bias that is introduced by the correlations can be corrected by using an artificially large deadtime. The deadtime was set to 35.83 ns to force the correct triples rate at the highest count rate. This artificial deadtime also works at lower count rates because the correlation bias is nearly linear both as a function of deadtime and of count rate.

The doubles and triples rates obtained from the ^{252}Cf data taken with the derandomizing OR circuit were corrected for deadtime and compared with the true values. The doubles rates were corrected with the equation

$$D = D_m \bullet \exp(4\delta S) \ ,$$

where D is the corrected doubles rate and the other quantities are defined above. The deadtime was set to 30.4 ns. The triples rates were corrected with

Dytlewski's equations using a deadtime of 35.83 μs. The results are shown in Fig. 4 as the ratio of corrected rates to true rates. This figure also includes the corrected rates for the ^{252}Cf source CR10 plus an AmLi source to show that this deadtime correction is not sensitive to the source type. For highly multiplying samples, however, additional small corrections will be needed to account for the correlations.

CONCLUSIONS

The new deadtime reduction circuit is suitable for use in thermal neutron coincidence counters using Amptek preamplifiers at count rates up to at least 1 MHz. More than a factor of two reduction in deadtime is possible. The circuit is about twice the size of an Amptek circuit board and can be mounted in the high-voltage junction box with the Amptek boards if desired.

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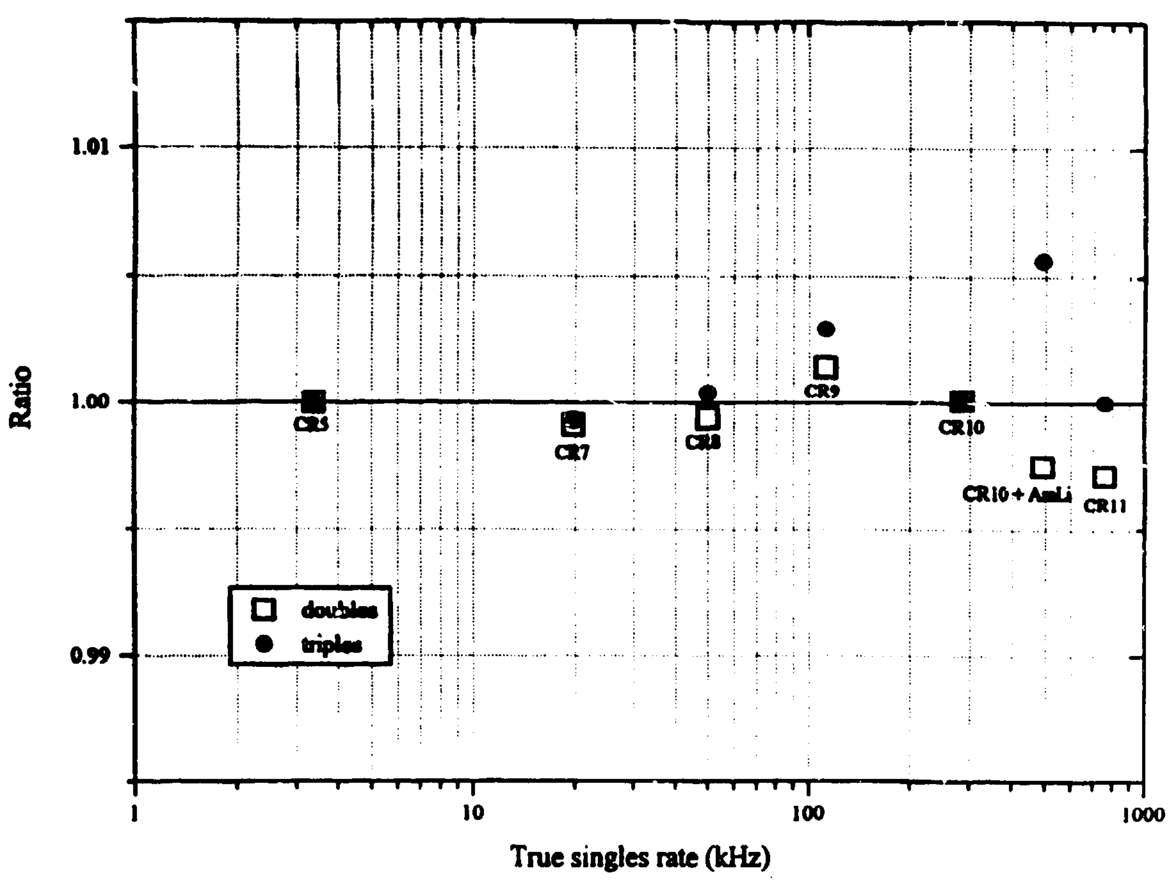

Fig. 4. Ratio of deadtime-corrected doubles and triples rates to true rates vs true singles rates for the derandomizing OR circuit.